An improved hand vein image acquisition method based on the proposed image quality evaluation system

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Abstract

In the part of hand vein image acquisition of vein recognition, we basically cannot get the images that are suitable for later process due to both the subjective factors and the objective factors. After a deep analysis on the main reasons including the different thickness of hands and mass of things on the hand, we propose the design of hand vein acquisition device based on the adaptive modulation control. The key part of the design is the proposed double-processing image quality assessment system: the first part of which involves the process of quality assessment based on the effective information of multidimensional histogram and the normalized information entropy; the second part involves adding the grey image variance and quantities of cross points with the proper weights, then two process will be made according to the final score: if the score is lower than the set threshold then image will be discarded, and on the other hand the brightness degree of the LED groups of the device will be adaptively adjusted according to the D-value of the score and the threshold so that we can get the high-quality hand vein image for later feature extraction and matching and get a higher recognition rate.

Keywords: hand vein recognition; adaptive control; two-set quality evaluation system; D-value

1 Introduction

With the development of biometric feature recognition and informative technology, the traditional identify technology cannot meet the demand of security. Vein recognition has become a new trend of biometric recognition with some great advantages [1-4]. And the currently main feature image evaluation method focuses on the fingerprint, iris and images of videos [5-7]. After a deep research and study on the existing method for image evaluation, we respectively take the statistical characteristics and structural characterristics after deburring as the feature parameters for evaluation function. The criterion of the first-set quality evaluation system we set is that: Calculating the two-dimensional histogram of hand vein images firstly, then we determine whether to store the image or not according to the spread condition of the pixel around the area of $G_1=G_2$; and then we calculate the information entropy of the stored image and compare the value with the pre-set threshold to get the second-stored vein image whose value is larger than the threshold (we set it 4.0 according to the recognition rate). In the second-set quality evaluation system, we firstly get the grey variance and number of cross points of the selected hand vein images, and then adopt the pre-set weight to calculate the final parameters by adding them up. The optimized weights we set are respectively 0.5826 and 0.4174 according to the recognition rate. And in the final, we get the final parameter to determine whether to leave the hand vein images for feature extraction, the normalized threshold we set in the final determination part is 0.55 according to the experiment result. And then we design the improved smart-control acquisition device based on the evaluation system, which can get the high-quality hand vein images for later feature extraction and matching and get a higher recognition rate.

2 Theory of quality evaluation system for hand vein images

In the procedure of capturing hand vein images, we usually could not get the high-quality hand vein images for later process, so it is essential for feature extraction and recognition to import quality evaluation function to realize the effective choice of the original vein images.

After a deep research and study on the existing method for image evaluation, we respectively take the statistical characteristics and structural characteristics after deburring as the feature parameters for evaluation function [8]. The explanation of the parameters is as follows:

(1) Statistical characteristics: The method censuses the spread parameters including the variance and entropy of the grey images based on the theory of transforming the original image into grey images, while the variance reflects the contrast degree and the entropy reflects the content of effecttive information.

(2) Structural characteristics: After the pre-process and the deburring process on the hand vein images, we choose the quantities of cross points of the images and the extracted ROI area as the evaluation parameters. On the one hand, we can know whether the images we obtain contain the proper amount of cross points for recognition; On the other hand,

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we can get the idea of the amount and effectiveness of the structural information of vein images.

3 Two-set of evaluation systems on hand vein images

3.1 FIRST-SET PART OF THE EVALUATION SYSTEM

In the first part of the evaluation system, we focus on the global spread and the global effectiveness of image information that are closely related with human vision, and we choose the two-dimensional distribution histogram and information entropy to realize the first-set evaluation.

3.1.1 Choice of images based on the two-dimensional distribution histogram

As the global information and features of images, the histogram of grey vein images can show the frequency distribution of grey of pixel and we adopt this parameter as one of the evaluation system. The traditional one dimensional grey histogram is the statistical distribution of isolated pixel. And we find that if the correlation between pixels could be got and analysed, we could get a better choice on the images. So we introduce the multi-dimensional distribution histogram for analysis.

In the theory of image processing, we define the multi-dimensional distribution histogram as follows: count the frequency of grey image *f(x,y)*, and then get $Num(G_1,G_2,G_3,\ldots,G_k)$, $G_1,G_2,G_3,\ldots,G_k \in \Omega$, and the Num stands for the frequency amount that when it meets the requirement that the pixel is G_1 and the *K-1* around the pixel is $(G_1,G_2,G_3,\ldots,G_k)$, and then we get the definition of *K* dimensional distribution histogram, and then normalizing the histogram value according to the max of frequency $max(Num(G_1,G_2,G_3,\ldots,G_k))$ to get $Norm(G_1,G_2,G_3,\ldots,G_k)$, which is called *K-D* normalized histogram.

$$Norm(G_1,G_2,G_3,\ldots,G_k) = \frac{Num(G_1,G_2,G_3,\ldots,G_k)}{\max\left(Num(G_1,G_2,G_3,\ldots,G_k)\right)} . \quad (1)$$

In the definition, we normalized the *Num* and max one of the frequency values to get the *K-D-log* normalized histogram.

$$Norm_{\log}(G_1,G_2,G_3,\ldots,G_k) = \frac{\log(Num(G_1,G_2,G_3,\ldots,G_k))}{\log(\max\left(Num(G_1,G_2,G_3,\ldots,G_k)\right))} . \quad (2)$$

The max one refers to the peak value of grey frequency value, and for calculating and reckoning compare we use the algorithm of LOG to realize the transformation based on the idea of the fractal dimension of complexity measure. And according to the advantages of statistics and distribution, we can get the key parameter to realize the choice of vein images for later analysis.

On the basis of the above definition, we define the certain pixel as G_1 and the pixels in the right-side region around it as G_2, and the criterion we set is: as for the high-quality vein images, the character of its two-dimensional histogram is that the frequency value of the region $G_1= G_2$ has a higher peak value and higher distribution density while the character of two-dimensional histogram for low-quality images is a lower peak value and scattered distribution in the region of $G_1= G_2$.

3.1.2 Choice of images based on the information entropy

The definition of entropy is proposed by Clausius in 1865 which is used for describing the disordered state of thermodynamic system, and then it was introduced into the field of information engineering. After a long period of development and improvement, the experts in the field of image information propose the definition of information entropy to represent the average amount of statistical information of the system [9-10].

In the proposed definition, we import the definition of complexor, and it is made up of $\{x_1,x_2,x_3,\ldots,x_n\}$, and then we can get the following definition on the condition of supposing x_i=v and the probability $p_i=P(x_i)$:

$$H(v) = -\sum_{i=1}^{n} p_i \log_z p_i \cdot \quad (3)$$

In the above definition, H(v) stands for the probability distribution function of the defined random variables.

In the field of digital image processing, the spread of different pixel points in the images are different in images, which results in different shape features of the vein images. The amount of statistical information will be much more with the richness of grey or color of the images, which means the quality will be better. According to this the rule, we could know that the much more difference of grey level and the more the statistical information, the better the hand vein image is. Supposing that the statistical probability of grey value m is P_m, and we can get the following calculating formula:

$$H(v) = \sum_{T=0}^{z33} p_m \log_z p_m \cdot \quad (4)$$

In the above definition, H stands for the information entropy of hand vein image, and the value range of m is [0, 255]. P_m stands for the probability of grey value m, and the criterion is that the higher the value of H, the better and the higher quality of the images.

In conclusion, the criterion of the first-set quality evaluation system we set is that: Calculating the two-dimensional histogram of hand vein images firstly, then we determine whether to store the image or not according to the spread condition of the pixel around the area of $G_1= G_2$; and then we calculate the information entropy of the stored image and compare the value with the pre-set threshold to get the second-stored vein image whose value is larger than the threshold (we set it 4.0 according to the recognition rate).

3.2 SECOND-SET PART OF THE EVALUATION SYSTEM

After the process of the first-set evaluation system, we obtain the preliminary hand vein images that can be used for subsequent analysis. Then we design algorithm to get the grey variance and numbers of cross points of the selected hand vein images, and then combine the two parameters by setting optimized weights, and then we get the final sample images for feature extraction and matching.

3.2.1 Calculation of grey variance

In this section, we define the selected images as the matrix M * N, and define *I(I,j)* as the grey value of the pixel on the line i and column j. Then we define Mean as the average value of the grey value, which can reflect the degree of brightness; On the other hand, we define Var as the grey variance of the image that reflects the contrast between the foreground and background of the images. The criterion is that: the bigger the value of the Mean and the Var, the better the vein image is.

$$Mean=\frac{1}{M\times N}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}I(i,j), \qquad (5)$$

$$Var=\frac{1}{M\times N}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}\left[I(i,j-Mean)\right]^{z}. \qquad (6)$$

3.2.2 Calculation of cross points

Although we have set the first-set part and the first one of the second-set of the evaluation system to select the high-quality vein images, there are still some selected images with low-quality bringing down the recognition rate, and after a deep analysis on the selected images, we find that there are great differences between the images after the pre-process on (especially the deburring process) the selected images, so we design the algorithm to calculate the number of the cross points. Then we find that the quality of the images differs with the number of cross points and the larger the number is the higher quality the image is.

In the pre-process of deburring, we improve it as the conditional deburring. The character, of which is that the connected points of lines and the turning points and T-shape branch points can be well kept after the deburring. But after a sudden amplification transformation we find that the conditional deburring can't realize the complete single pixel processing, which is shown as follows:

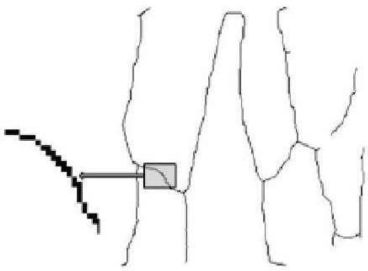


FIGURE 1 Amplification of the vein images after conditional deburring

After a deep analysis on the phenomenon mentioned above, we adopt the template process algorithm after the self-defined improved conditional deburring process on the vein images, and it can remove the single-pixel point to get the real cross points of the images. We divide the existing non-single pixel into two kinds, and as for the first kind shown in Figure 2, we need to cut off the non-single pixel according to the final matching because that these pixels are redundant.

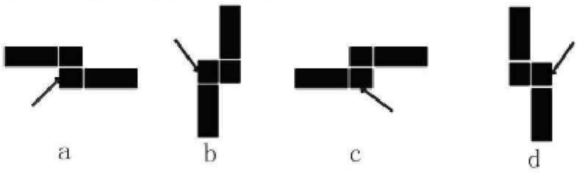


FIGURE 2 The first kind of non-single pixels

The template we adopt is shown in Figure 3, the centre of the template is the reference central point. In the chart, "1" stands for the point in the targeted images while "0" stands for that in the background images, and "x" stands for the points of the targeted images that are used for later analysis on the one hand, on the other hand, it stands for the points of the background images.

(a)

x	1	x
0	0	1
0	0	x

(b)

0	0	x
0	x	1
x	1	x

(c)

x	1	x
1	0	0
x	0	0

(d)

x	0	0
1	0	0
x	1	x

FIGURE 3 The designed template for the first kind of non-single pixels

The criterion we set here is that we firstly choose to cut off some pixels related to the template's central point's so as to decrease the width of the vein, and at the same time we cut off the points the arrow pointing to in Figure 3 (a). Then we adopt the other three pre-defined templates to realize cutting the other points off to leave the pixels that meet the requirements. Then we adopt the iterative operation with the existing operation until the first non-single pixels are cut off completely.

Then we can conclude from the analysis that the second kind of non-single pixels are as follows:

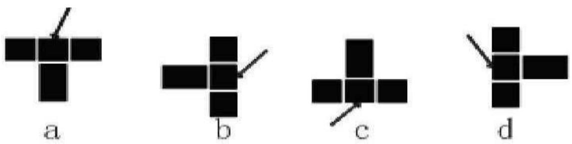


FIGURE 4 The second kind of non-single pixels

In this part, we design another template that are suitable for the second kind of non-single pixels based on the design of the first kind of templates.

(a)

x	0	x
1	1	1
x	1	x

(b)

x	1	x
1	1	0
x	1	x

(c)

x	1	x
1	0	1
x	0	x

(d)

x	1	x
0	0	1
x	1	x

FIGURE 5 The designed template for the second kind of non-single pixels

After the process of cutting the pseudo cross points off, we can get the following vein images as shown in Figure 6 for later analysis. On the other hand, we find that the cross points of the vein image can be easily obtained after the designed templates' process, and we could design a formula to get the number of the cross points so that we can determine whether the images can be used for recognition.

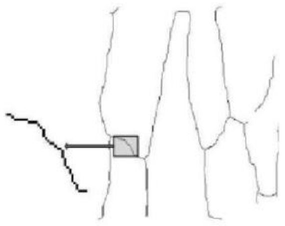


FIGURE 6 The local amplification effect image after the templates' process

In the second-set quality evaluation system, we firstly get the grey variance and number of cross points of the selected hand vein images, and then adopt the pre-set weight to calculate the final parameters by adding them up. The optimized weights we set are respectively 0.5826 and 0.4174 according to the recognition rate. And in the final, we get the final parameter to determine whether to leave the hand vein images for feature extraction, the normalized threshold we set in the final determination part is 0.55 according to the experiment result.

4 Realization of improved smart-control acquisition device based on the evaluation system

Through the process of the proposed evaluation system, we find that the final recognition rate improves a lot after leaving some low-quality vein images. So we import the thought of feedback modulation based on the evaluation system to realize the smart-control of the capturing device and increase the recognition rate in the end.

4.1 DISCUSSION ON THE CONTROL METHOD ON THE CAPTURING DEVICE

According to the imaging principle, we could know that the vein images are obtained on the condition of specified wavelength of light source, so it is required that the voltage should remain in a stable value, and we have realized keeping the homogeneity and stability of the near-infrared light source by adding the control on the power-supplying circuit and equipped the capturing device with light guide plate. And concluding from the circuit theory we can know that the strength of the light source is proportional to the electrical current, so we choose to control the light strength by the way of controlling the electrical current.

We find that the changing trend of the quality evaluation parameter will go up with the increase of the current in a certain range, but it will go down after a certain peak value, so we can realize the control on the capturing of hand vein image to obtain high-quality image by the control on the electrical current. The method we adopt is the PWM control on the circuit.

4.2 REALIZATION OF THE DEVICE

The procedure of capturing hand vein images is as follows: set the parameters of the capturing device by the self-programed software, then starting capturing and calculating the parameters of the evaluation system by the self-programed software, and then take actions mentioned above to obtain the high-quality vein images.

The concrete procedure of the control is as follows:

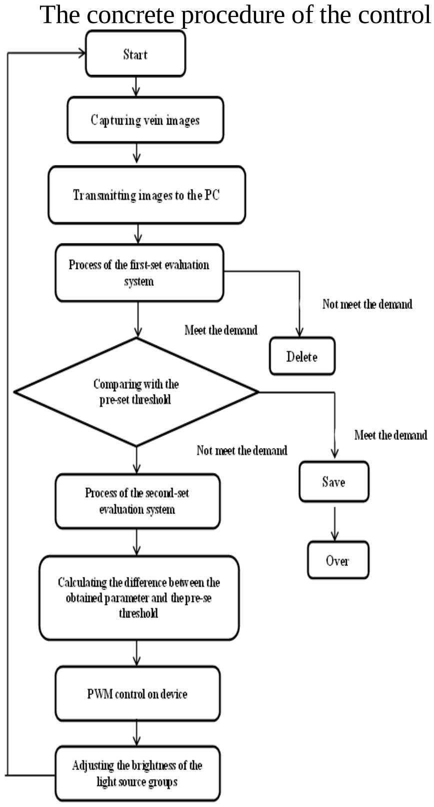
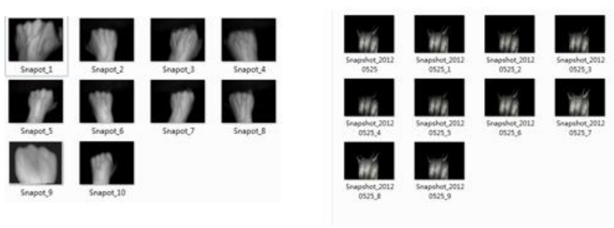


FIGURE 7 The flow chart of the smart-control system

5 Experiment result and discuss

At the beginning of the study on hand vein recognition, we design a capturing device to establish the database of hand vein images for later recognition, but it cannot get a good recognition result, the beginning vein image acquisition method concentrates on transmission imaging mode uses simple control method without feedback signals to realize the control on the LED groups.



a) b)

FIGURE 8 Databases of the hand vein images of one volunteer: a) Acquisition device before optimized; b) Acquisition device after optimized

a) b)

FIGURE 9 The certain sample of the databases: a) Acquisition device before optimized; b) Acquisition device after optimized

Based on the above disadvantages of the current devices and after a deep analysis on the main reasons including the different thickness of hands and mass of things on the hand, we propose the design of hand vein acquisition device based on the adaptive modulation control. The key part of the design is the proposed double-processing image quality assessment system: the first part of which involves the process of quality assessment based on the effective information of multidimensional histogram and the normalized information entropy; the second part involves adding the grey image variance and quantities of cross points with the proper weights, then two process will be made according to the final score: if the score is lower than the set threshold then image will be discarded, and on the other hand the brightness degree of the LED groups of the device will be adaptively adjusted according to the D-value of the score and the threshold so that we can get the high-quality hand vein image for later feature extraction. The following two databases of hand vein images are respectively obtained by the two generation set of devices, and it is obviously that the smart-control device can get a better images.

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